

RCRA – Technologies for Puerto Rico



14 Years of EPA Region 2 and ORD Research Collaboration

Produced by:
U.S. EPA Region II Enforcement & Compliance Assistance Division
RCRA Compliance Branch



RCRA – Technologies for Puerto Rico

- Alternative Closure Caps: A Lower Cost and Environmentally Sound Option in Puerto Rico

Emmie McCleary, SEMD, US EPA Region V

- A leachate study in landfills in PR; developing a protocol for low-cost sampling

Melitza Crespo-Medina, CECIA IAUPR

- 14 Years of Region 2 RCRA and ORD Collaborative Landfill Work in Puerto Rico. Next steps:

- Innovative Landfill Leachate Treatment
- Pilot Alternative Closure Cap Design and Installation
- Other Proposed Projects

Carl Plossl, RCRA Compliance Branch, ECAD, US EPA Region II



Past R2 RCRA/ORD Collaborative Landfill Work in Puerto Rico

EPA/600/R-12/700

An Evaluation and Analysis of Past Landfill Closures
in Puerto Rico as Guidance for Current and Future
Closures

USEPA Task Order 99

Order: EP-C-05-060

Prepared for:
United States Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Cincinnati, Ohio

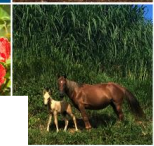
Prepared By:
Innovative Waste Consulting Services, LLC
Gainesville, Florida

Under Subcontract To:
RTI International
Research Triangle Park, North Carolina

September 2011



EPAN00R-21003 | February 2002 | www.epa.gov/research



DRAFT – August 2010. FOR AGENCY REVIEW

PUERTO RICO MUNICIPAL SOLID WASTE
LANDFILL EVAPOTRANSPIRATION COVER
DESIGN GUIDANCE

ment:
TRANSPIRATION, AND
OTRANSPIRATION
RICO



Puerto Rico
Solid Waste Landfills
Metal Areas

EPA Office of Research
and Development Regional
Applied Research Effort

RARE Proposal:
Puerto Rico Leachate Study



oratory



VIEW

Produced by:
U.S. EPA Region II Enforcement & Compliance Assistance Division
RCRA Compliance Branch



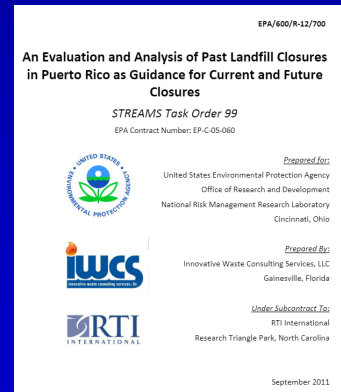
Past Projects

- RARE Project: An evaluation and analysis of past landfill closures
- Study and Draft Guidance: Evaluated the potential for evapotranspirative landfill covers in PR
- 4th Congress on the Environment Presentation: *Puerto Rico Solid Waste Landfills Impacts on Coastal Areas*
- Joint Seminar/Roundtable and Field Study: ET covers and other landfill issues
- Low-cost, Landfill Waste Extent Determinations
- RARE Project: Landfill leachate characterization and study focusing on open dumps
- EPA Guidance Document: *Design, Implementation, and Approval of Evapotranspiration Covers in Puerto Rico*



Past Projects (continued)

- RARE Project (STREAMS Task Order 99):
 - Evaluation & Analysis of Past Landfill Closures as Guidance for Current and Future Closures
 - Project Description
 - Evaluated previous MSWLF closure successes and shortcomings
 - Reviewed historical documentation on engineering design and controls in place at the time the landfill closed
 - Principal Findings
 - No groundwater monitoring
 - No ongoing beneficial use
 - Significant cover permeability and integrity failures
 - No evident regulatory follow-up



Past Projects (continued)

- RARE Project (STREAMS Task Order 99):
 - An Evaluation and Analysis of Past Landfill Closures in Puerto Rico as Guidance for Current and Future Closures
 - Additional, informative findings:
 - The ORD, EPA, and contractor team's pre-study assessment of multiple municipal landfill closures found that the existing earthen covers, while overgrown and, mostly, unmaintained, were demonstrably in relatively good condition.
 - Most of the selected sites were unavailable or inaccessible to the field team. Only 4 sites were studied, and they were not representative.



Past Projects (continued)

Eroded Western
Edge of Rincón
Municipal Landfill
#2



Past Projects (continued)

RARE Project (STREAMS Task Order 99):

Most of the
selected sites
were unavailable
or inaccessible to
the field team



Past Projects (continued)

- **Study and Draft Guidance:**
 - Evaluated the potential for evapotranspirative (ET) landfill covers in Puerto Rico
 - Provided the basis for a landfill ET closure demonstration project and the justification for a formal guidance manual

DRAFT – August 2010. FOR AGENCY REVIEW

PUERTO RICO MUNICIPAL SOLID WASTE LANDFILL EVAPOTRANSPIRATION COVER DESIGN GUIDANCE

Prepared for:

U.S. Environmental Protection Agency
National Risk Management Research Laboratory
Cincinnati, Ohio



Prepared by:

RTI International
Research Triangle Park, North Carolina



Innovative Waste Consulting Services, LLC
Gainesville, Florida

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Past Projects (continued)

- ET Study and Draft Guidance:

- Determined that:

- Year-round growing season
 - High solar radiation
 - Increased evaporation and transpiration

compensated for the higher precipitation levels in much of Puerto Rico and allowed for the effective use of ET covers in landfill closures



Past Projects (continued)

• 4th Congress on the Environment Presentation:

EPA — Puerto Rico Solid Waste Landfills Impacts on Coastal Areas

Puerto Rico Solid Waste Landfills Impacts on Coastal Areas

Thabet Tolaymat PhD, ORD
Carl Plossl, USEPA Region 2



Arecibo Landfill

- Siting Challenges
 - Potential Impact on Natural Reserves
 - Endangered/Threatened Species
 - Puerto Rico Endangered Species Habitat contiguous and/or directly adjacent:
 - Brown pelican (*Pelecanus occidentalis*)
 - American peregrine falcon (*Falco peregrinus anatum*)
 - Puerto Rico Threatened Species Habitat contiguous and/or directly adjacent:
 - Caribbean coot (*Fulica caribaea*)
 - Masked Duck (*Oxyura dominica*)
 - Ruddy Duck (*Oxyura jamaicensis*)
 - West Indian whistling-duck (*Dendrocygna arborea*)



Background

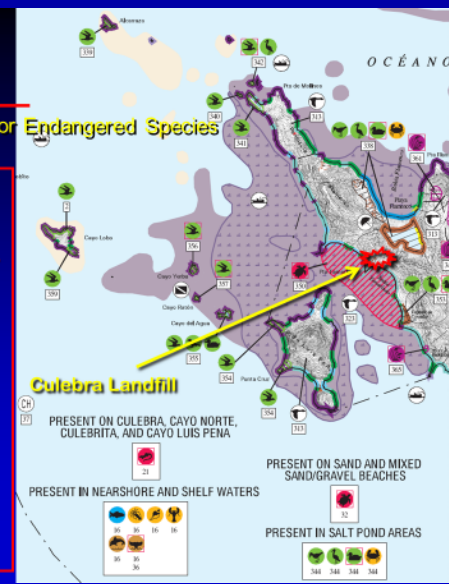
- PR Landfill Locations in Coastal Areas
 - Closed landfills ★



Culebra Landfill

- Risks to Natural Reserves &/or Endangered Species

- Black-necked stilt
- Blue-winged teal
- Caribbean coot PR-Threatened
- Common moorhen
- Least grebe PR-Thrd.
- Masked duck PR-Thrd.
- Ruddy duck PR-Thrd.
- West Indian whistling-duck PR-Thrd.
- White-cheeked pintail
- Pelagic fish
- Reef fish
- Blue land crab
- Caribbean spiny lobster
- Octopus
- Queen conch
- Dolphins
- Humpback whales Fed-Endangered
- Mabuya PR-Threatened.
- Green sea turtle Fed-Thrd.
- Hawksbill sea turtle Fed-End.
- Leatherback sea turtle Fed-End.



Past Projects (continued)

- Low-cost, Landfill Waste Extent Determinations
 - At unlined landfills in Puerto Rico covered by Order on Consent with EPA, the extent of the horizontal and vertical perimeter of the fill area must be determined, or the perimeter provided by the facility to EPA must be verified, and mapped with survey-grade, sub-meter accuracy
 - Municipal landfill financial resources are quite limited
 - EPA has piloted a low-cost extent determination at the Cayey Landfill employing ground-penetrating radar



Past Projects (continued)

- Low-cost Landfill Waste Extent Determinations

Cayey Landfill Solid Waste Extent
Determination
EPA/ERG Prime Contract #: EP-
W-15-006

isfpe, llc
Professional Engineers



Past Projects (continued)

- Seminar/Roundtable and Field Studies
 - Evaluated six PR landfills for ET covers during field visits
 - Culebra, Santa Isabel, Cayey, Yauco, Juana Díaz, and Lajas
 - Organized seminar/roundtable with the Puerto Rico Environmental Quality Board (now DNER), the regulated community, and stakeholders on:
 - ET landfill cover suitability, design, and permitting/regulating
 - Low-cost landfill waste extent delineations employing a mix of direct sampling and geophysical techniques
 - Proposed PR leachate characterization and treatment study (RARE Project)



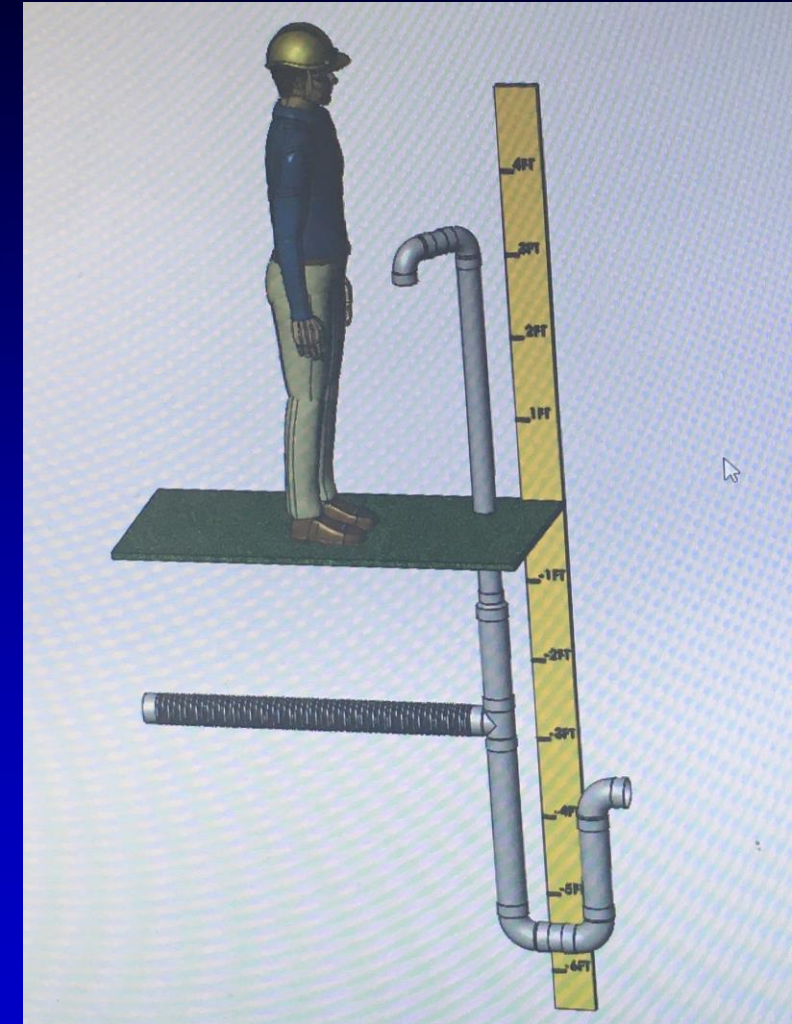
Past Projects (continued)

- Joint Seminar and Field Study in Puerto Rico:
 - Evaluated six PR landfills for ET covers during field visits



Past Projects (continued)

- RARE Project:
 - Landfill leachate characterization and study focusing on open dumps
- EPA Guidance Document:
 - Design, Implementation, and Approval of Evapotranspiration Covers in Puerto Rico*



Current R2 RCRA/ORD Collaborative Landfill Work in Puerto Rico



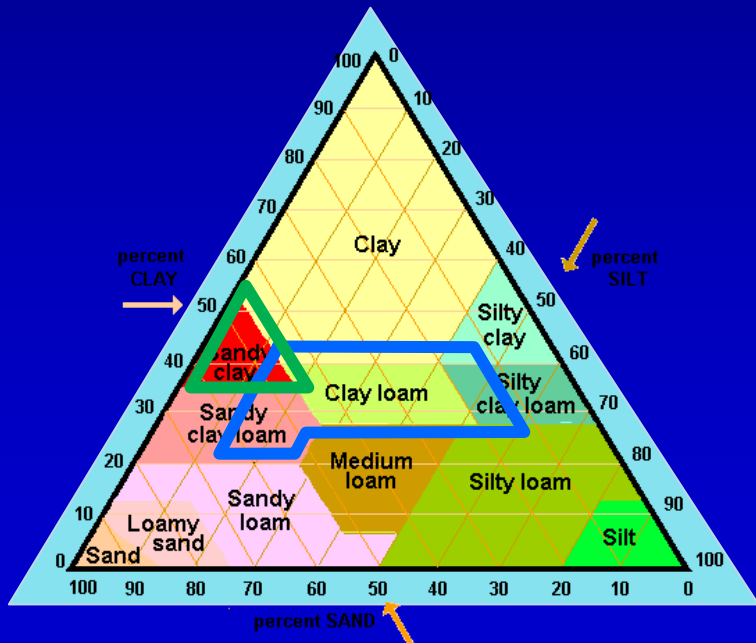
Current Project: Santa Isabel Landfill

- Pilot Alternative Closure Cap Design and Installation
 - Landfill estimated to release some 7 million gallons of leachate to groundwater each year (pre-closure)
 - Closure mandated under a federal judicial consent decree overseen by EPA
 - Intermediate cover of 12-inches of soil known to be in place
 - Significant municipal financial constraint limit standard closure options
 - Relatively low annual precipitation
 - PR-DNER and EPA have agreed that EPA will oversee an alternative closure employing an ET cap designed and installed in accord with the EPA guidance document: *Design, Implementation, and Approval of Evapotranspiration Covers in Puerto Rico*



Current Projects: Santa Isabel Landfill (continued)

- **Pilot Alternative Closure Cap Design and Installation**
 - ET closure cap design by Tarek Abichou, PhD, PE and Steve Rock, ORD
 - Simulations suggest that the performance of a 45-cm-thick (18-inch) soil cover, constructed with locally available soils (clay loam or silty clay loam) and vegetated with local grasses, can have similar percolation rate to a compacted clay cover



Santa Isabel Landfill Alternate Final Closure Cover Design

By

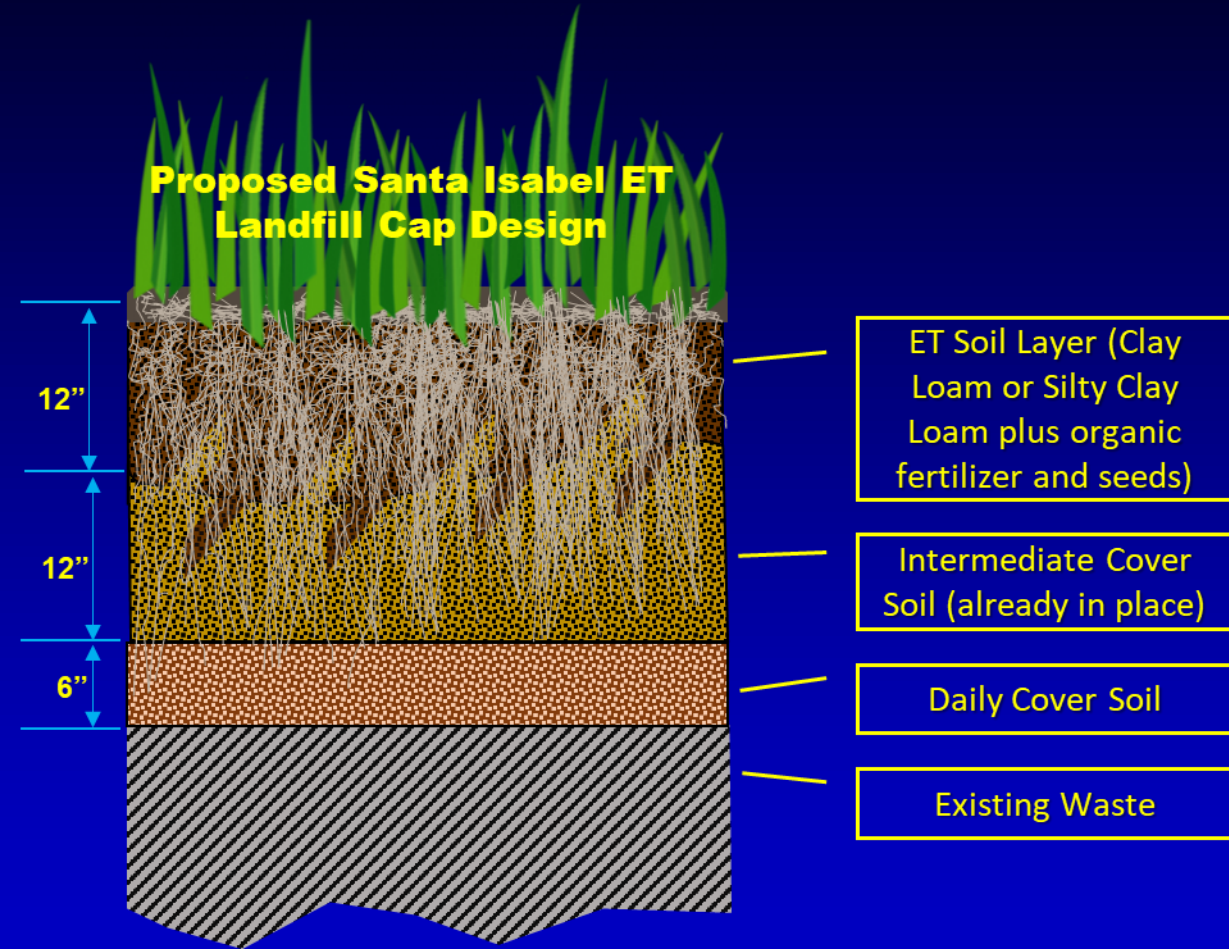
Tarek Abichou, Ph.D., P.E.

Steve Rock, EPA Office of Research and Development



Current Project: Santa Isabel Landfill (continued)

- EPA Office of Research & Development Design
 - ET Cover
 - Modeled percolation rate through a RCRA-prescribed compacted clay cover under Santa Isabel climatic conditions was found to be 28 mm/year or 3.1% of precipitation.
 - Simulations indicate that the performance of a 450-mm (18") thick soil cover, constructed with locally available soils (clay loam or silty clay loam) and vegetated with local grasses, can have similar percolation rate to a compacted clay cover.
 - Experience suggests a minimum of 600-mm (2-ft) ET cover as a safety factor. Intermediate, in-place cover would be incorporated into the ET cover.
 - Soil to be classified as Clay Loam or Silty Clay Loam (USDA, Chart)
 - Appropriate native species seed mix (generally native grasses) must be used to establish a naturally-sustaining plant cover that will thrive under ambient soil and climate conditions.



Current Projects: ET Cover Seminar and Workshop

- ET Cover 3-Day Seminar and Workshop
 - Follows the publication of US EPA's March 2022 guidance document-- *Design, Implementation, and Approval of Evapotranspiration Covers in Puerto Rico*
 - EPA CEPD, USDA RD, and other stakeholders throughout Puerto Rico have expressed support for the implementation of evapotranspiration covers throughout Puerto Rico as a more effective and affordable alternative final landfill cover solution when compared to compacted clay covers



Current Projects ET Cover Seminar and Workshop (cont.)

- PR-DNER has sought further guidance on how ET Covers could be designed, implemented, and approved across five different Ecozones in Puerto Rico
 - Two seminar portions are planned for:
 - Regulators, funding agencies, and any other government personnel
 - Consultants, engineers, academia, and any other technical stakeholders
 - An additional day for a field trip and closure cap design exercise





Future? R2 RCRA/ORD Collaborative Landfill Work in Puerto Rico

Future? Projects (continued)

- Innovative Landfill Leachate Treatment:
 - Piloting Lower Cost and Environmentally Sound Options for PR
- Leachate Release Monitoring & Characterization from Unlined Landfills
 - Developing protocols modeling, sampling, and permit requirements
- Increasing the Use of Waste Tires and Other Recycled Materials in Landfill Design, Construction, Operation, and Closure
- Proposed EPA Guidance Document:
 - *Design, Implementation, and Approval of Evapotranspiration Covers in the Caribbean and Latin America*
- Innovative Landfill Gas Treatment:
 - Piloting Lower Cost and Environmentally Sound Options for PR
- Karst Terrane Groundwater Monitoring Plan



Future? Projects (continued)

- Innovative Landfill Leachate Treatment

- Issue:

- Leachate is liquid that has passed through or emerged from solid waste and contains soluble, suspended or miscible materials removed from such waste
 - Leachate from municipal landfills will be contaminated with hazardous constituents such as toxic chemicals and heavy metals, complex organic compounds, concentrated oxygen depleting nutrients (high BOD/COD values), and microbial pathogens
 - Uncontrolled leachate discharges from the existing unlined landfills (open dumps) of some 230 million gal/year remain a wide-spread and continuing source of environmental risk



Future? Projects (continued)

- Innovative Landfill Leachate Treatment

- More issues:

- Extremely limited municipal and Commonwealth financial resources have precluded traditional treatment solutions
 - Inaccessibility of sewer system hook-ups (manholes), pretreatment requirements, and POTW resistance limit the standard alternative to onsite treatment
 - Recirculation is excluded as most are unlined landfills
 - Mandated subsurface leachate interception systems have exacerbated the issue by increasing the volume of collected leachate



Future? Projects (continued)

- Innovative Landfill Leachate Treatment

- Even more issues:

- On-site tank/pond storage and offsite disposal via tanker truck transport to a wastewater treatment plant (WWTP) may be economically unsustainable and the practice of re-discharging (dumping) is endemic
 - The closing of open dumps and the Commonwealth-wide shift to lined landfills with leachate collection systems will:
 - Significantly increase the volume of collected leachate without any island-wide plan to manage such
 - Further burden DNER's limited staff with the technically-complex permitting, inspection, and other compliance monitoring for these landfill leachate collection, storage, treatment, and disposal systems



Future? Projects (continued)

- Innovative Landfill Leachate Treatment

- To meet this need:

- Design, develop, and carry out a pilot study or studies on affordable, regulatory-compliant, on-site treatment of leachate from municipal landfills
 - Based on the outcome of pilot studies, develop and distribute an onsite leachate treatment guidance manual
 - Provide technical training to DNER staff on permitting, inspection, and other compliance monitoring for landfill leachate collection, storage, treatment, and disposal systems



Future? Projects (continued)

- Innovative Landfill Leachate Treatment

- To meet this need, also:

- Advise on establishing a central PRASA pretreatment permit application officer/office and a standard application/review/modification/approval process for the discharge of the leachate into the PRASA systems, both via direct sewer/manhole connection and via tanker truck delivery to a WWTP (the latter as only temporary measures)
- Assist with the establishment of a central PRASA office for the tracking and reporting of the monthly discharge of leachate into the PRASA systems by each landfill with reporting to DNER for compliance tracking and verification

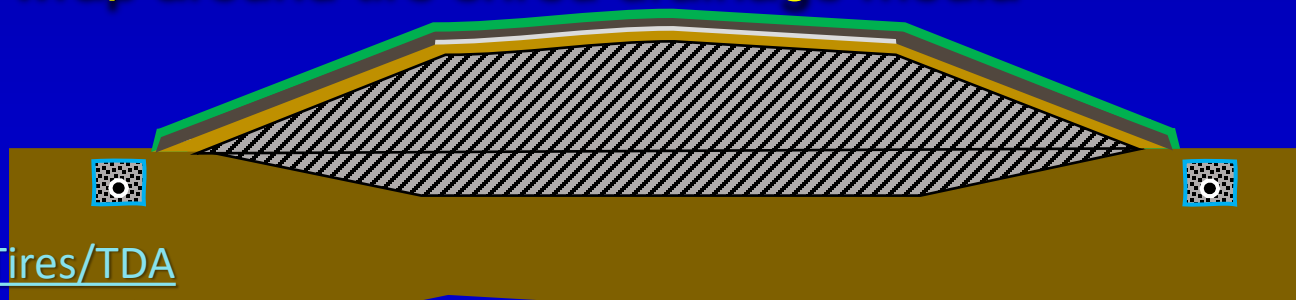
Future? Projects (continued)

- Issue: Puerto Rico generates and disposes nearly five million scrap tires each year with no clear, sustainable management plan for recycling or disposal.
- Proposal:
 - Develop a Guidance on the Use of Waste Tires in Landfill Design, Construction, Operation, and Closure in PR
 - Draft a protocol for the permitting of waste tires in landfill design, construction, operation, and closure



Future? Projects (continued)

- Developing a Guidance on the Use of Waste Tires in Landfill Design, Construction, Operation, and Closure in PR
 - Example:
 - Tire-derived aggregate (shredded tire chips) can be used as gravel-substitute drainage material in landfill gas and leachate collection and removal systems.*
 - Perimeter, toe-of-the-slope trench for interception, collection and treatment of leachate with:
 - » 20-acre (80,900-m² or 8.09-ha) L=2xW landfill
 - » 1-m wide by 1-m deep trench and 10-cm perforated pipe
 - » Geotextile wrap around tire shred drainage media



* <https://www.calrecycle.ca.gov/Tires/TDA>

California Integrated Waste Management Board (CIWMB, now CalRecycle) has guidelines regarding use of tire shreds in landfill applications. These uses include leachate drainage material, final cover foundation layer, operations cover, and gas collection layer.

Future? Projects (continued)

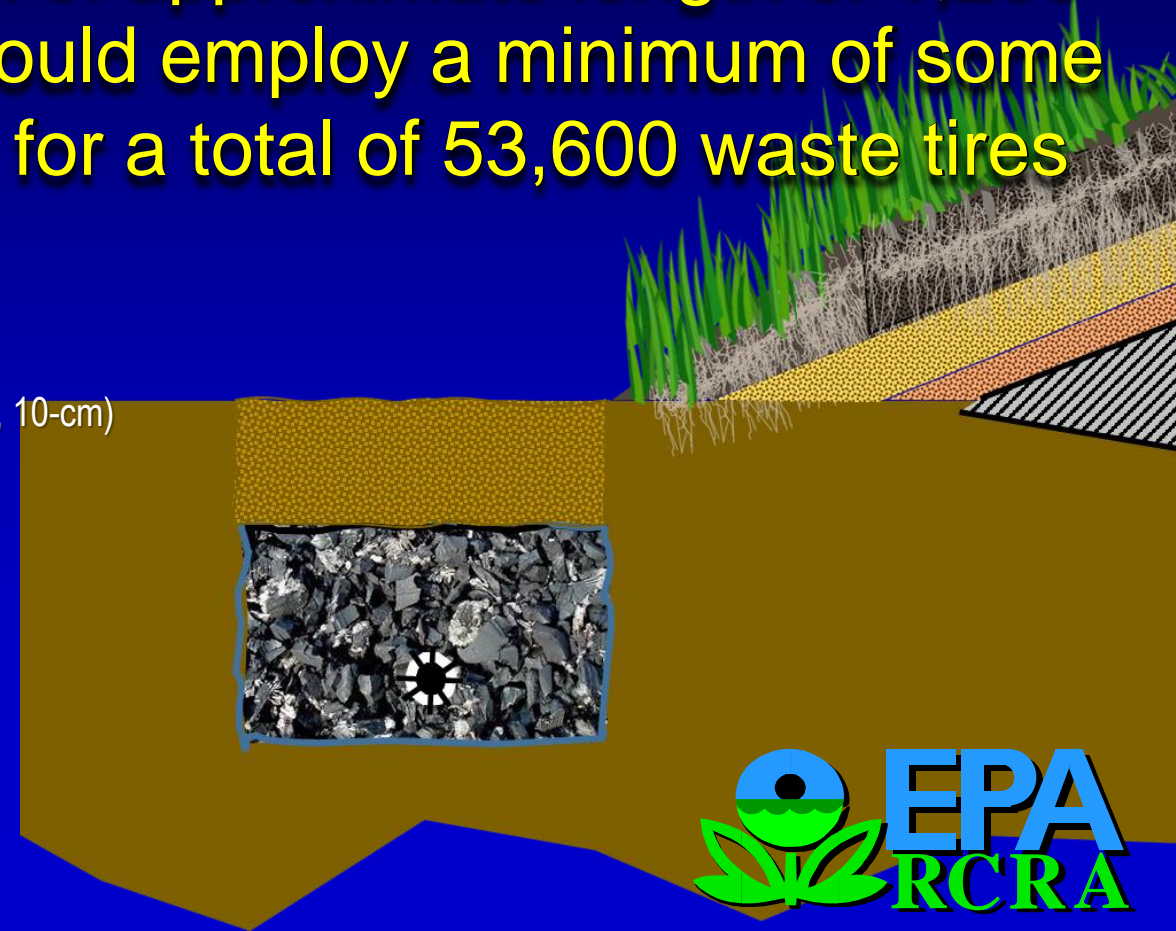
- **Example: Tire-derived aggregate as gravel-substitute drainage material**
 - With a 1-m wide by 1-m deep trench of approximate length of 1,200-m, and 10-cm perforated pipe, we could employ a minimum of some 488,000-kg of compacted tire shred for a total of 53,600 waste tires

Given

- 9.1-kg/tire, and 745-kg/m³ for compacted, in situ tire shreds
- 1,200-m perimeter trench of initial 1-m x 1-m cut
- Geotextile embedded in trench
- 15-cm of tire shreds placed on the bottom of the trench as a base material for the pipe (4-in, 10-cm)
- Pipe fill 10-cm less pipe itself
- After the landfill gas collection pipe placement, an additional 30-cm placed over the pipe
- Geotextile wrapped over tire shed filter
- Backfilled with soil

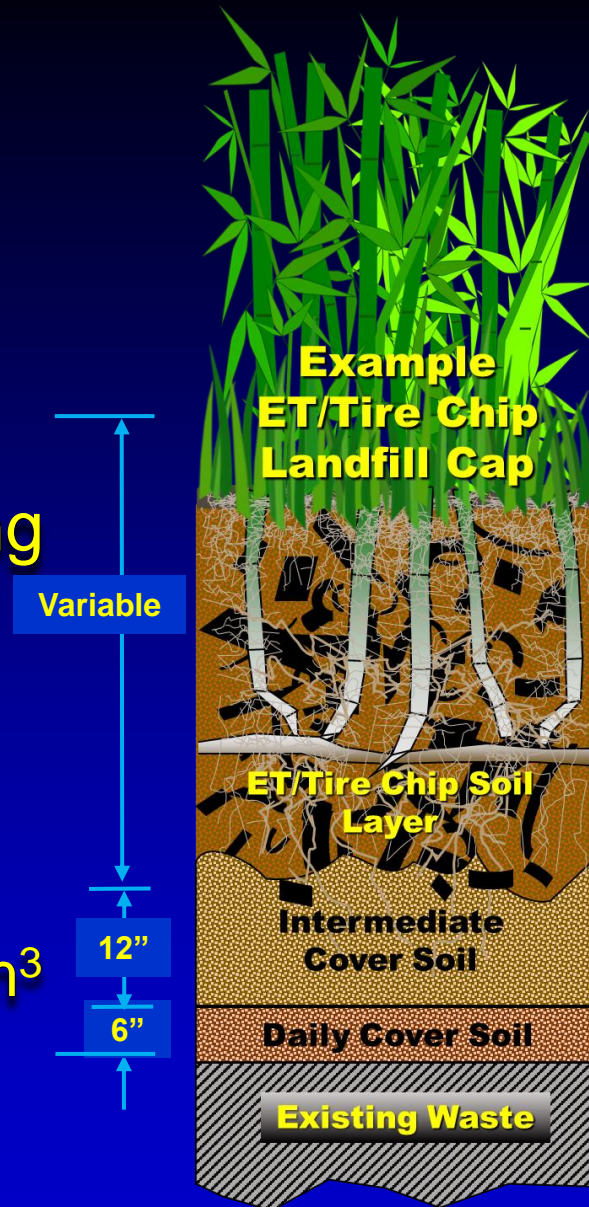
Solution

- Total cross section fill of 0.542-m² of tire shred
- Total fill of 654-m³ of compacted tire shred
- Total fill of 488,000-kg of compacted tire shred
- Total fill of 53,600 tires worth of tire shred
- Geotextile wrap of width 3.4-m (w/15-cm overlap)



Future? Projects (continued)

- Example: ET Cover using manufactured soil employing used tires
 - Tire-derived aggregate (shredded tire chips) can be used as media for enhanced biomass growth (increasing bio-attenuation of landfill gas)
 - Example calculation:
 - At 55 tires per cubic meter of chips
 - For a 20-acre (80,900-m² or 8.09-ha) cover with a 2.5-ft (0.75-m) ET cap layer, we could employ some 24,700- m³ of tire chips or 1.4-million tires within the soil mixture (~30% of Puerto Rico's annual waste tire burden)



Future? Projects (continued)

Employing Other Recycled Materials/Wastes

- ET Cover using manufactured soil employing storm debris
 - Example calculations
 - For a 20-acre (80,900-m² or 8.09-ha) cap for landfills along the similar, drier Puerto Rico local climate zones, the ET portion of the cover system would require some 10 to 24-inches of engineered soil. Employing a mix of mulched vegetative storm debris and local soils would employ 48,000 to 65,000 cubic yards of mulch.
 - Puerto Rico landfills that the owner/operators have indicated interest in closing with ET covers, and whom EPA/ORD believes are suitable for ET covers, include:

ET/Mulch Cap Examples	Landfill	Closure area (acres)	Mulch “demand” (cu yds)
	Culebra	7	20,000
	Juana Diaz	15	50,000
	Lajas	13	40,000
	Cayey	21	70,000
	Yauco	30	100,000
	Cabo Rojo	10	30,000
	Guayama	22	70,000
	Santa Isabel	15	50,000

Totaling some 430,000 cu yds of mulch “demand.”



Future? Projects (continued)

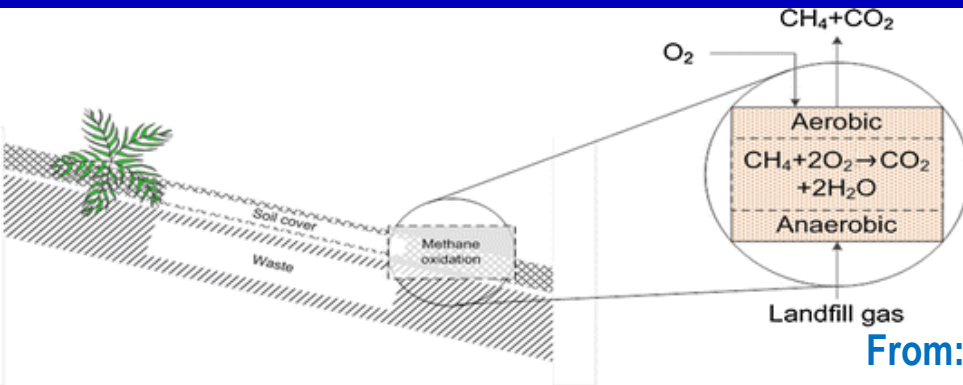
- Innovative Landfill Gas Treatment: Piloting Lower Cost and Environmentally Sound Options for PR
 - Landfill gas is about 50% methane & 50% carbon dioxide with small amounts of other toxins
 - Methane is a significant greenhouse gas that contributes to global climate change
 - Landfills are the 3rd largest human-related source of methane in the US
 - Landfill gas emissions from existing open dumps in Puerto Rico remain a widespread and continuing source of environmental and human health risk
 - EPA closure orders mandate landfill gas collection and treatment
 - Extremely limited municipal and Commonwealth financial resources, limited enforcement efforts, & the smaller size of many of the open dumps have precluded standard active gas collection systems



Future? Projects (continued)

- Innovative Landfill Gas Treatment

- Proposal: Design, develop, and carry out pilot stud(ies) on affordable, regulatory-compliant, sustainable on-site collection and treatment of landfill gas from municipal landfills employing:
 - Suitable passive gas wells and treatment systems (e.g., solar-powered, continuous-ignition, passive flares, modular bio-reactors, ...)
 - Enhanced methane bio-oxidation soil caps
- Based on the outcome of pilot studies, develop and distribute an onsite landfill gas collection and/or treatment guidance manual



From: [Landfill methane oxidation in soil and bio-based cover systems: a review](#)



Future? Projects (continued)

- **Karst Terrane Groundwater Monitoring Plan**
 - Five of the existing EPA Landfill Orders address open dumps within karst terrane
 - Karst presents significant challenges to effective groundwater monitoring and aquifer protection
 - Contamination may be fed directly to a karst aquifer via leaching or overland flow to a sinkhole with little or no attenuation and may contaminate downgradient wells, springs, and sinkholes within a few hours or a few days
 - A system of reasonably spaced monitoring wells placed down-gradient from a landfill, suitable for most granular aquifers, is unlikely to detect pollutants moving through conduits in bedrock of most karst
 - Existing landfill groundwater protection regulations, both Commonwealth and Federal, do not address the specific challenges inherent in karst terrane



Future? Projects (continued)

- Karst Terrane Groundwater Monitoring Plan
 - Proposal: Develop site-specific groundwater monitoring plans for two of the landfills within karst (Moca and Florida). These plans would:
 - Account for the special challenges of monitoring ground water in karst terranes as addressed in the EPA publication: *Ground-Water Monitoring in Karst Terranes*
 - Be economically and technically sustainable by municipalities
 - These plans would then serve as guidance for the development of groundwater plans for the remaining landfills as well as a host of other RCRA facilities within Puerto Rico's extensive karst belt



For More Information



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